Experience with NEG-Coated Vacuum Chambers at the ESRF

Roberto Kersevan †

AGENDA:

- *The European Synchrotron Radiation Facility*
- *Machine Parameters*
- *Conductances*
- *Gas loads*
- *NEG-Coating*
- *Pumping*
- *Machine Physics Issues*
- *References and Acknowledgements*

† *Reporting for the ESRF Vacuum Group*

- *The European Synchrotron Radiation Facility*

Bird's Eye View of the ***Polygone Scientifique Louis Néel*** and adjacent research areas, hosting the ESRF, ILL, EMBL, CNRS, CEA, and more.

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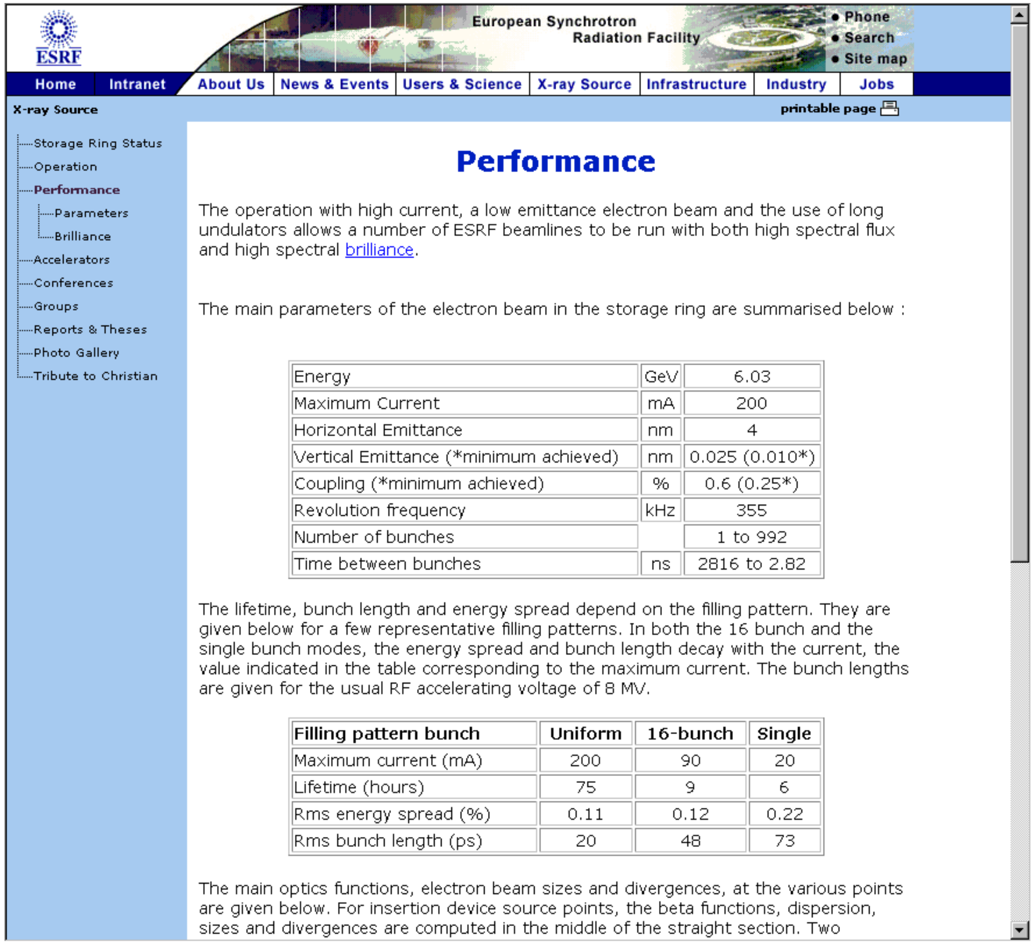
- *Machine Parameters*



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Performance

The operation with high current, a low emittance electron beam and the use of long undulators allows a number of ESRF beamlines to be run with both high spectral flux and high spectral brilliance.

The main parameters of the electron beam in the storage ring are summarised below :

Energy	GeV	6.03
Maximum Current	mA	200
Horizontal Emittance	nm	4
Vertical Emittance (*minimum achieved)	nm	0.025 (0.010*)
Coupling (*minimum achieved)	%	0.6 (0.25*)
Revolution frequency	kHz	355
Number of bunches		1 to 992
Time between bunches	ns	2816 to 2.82

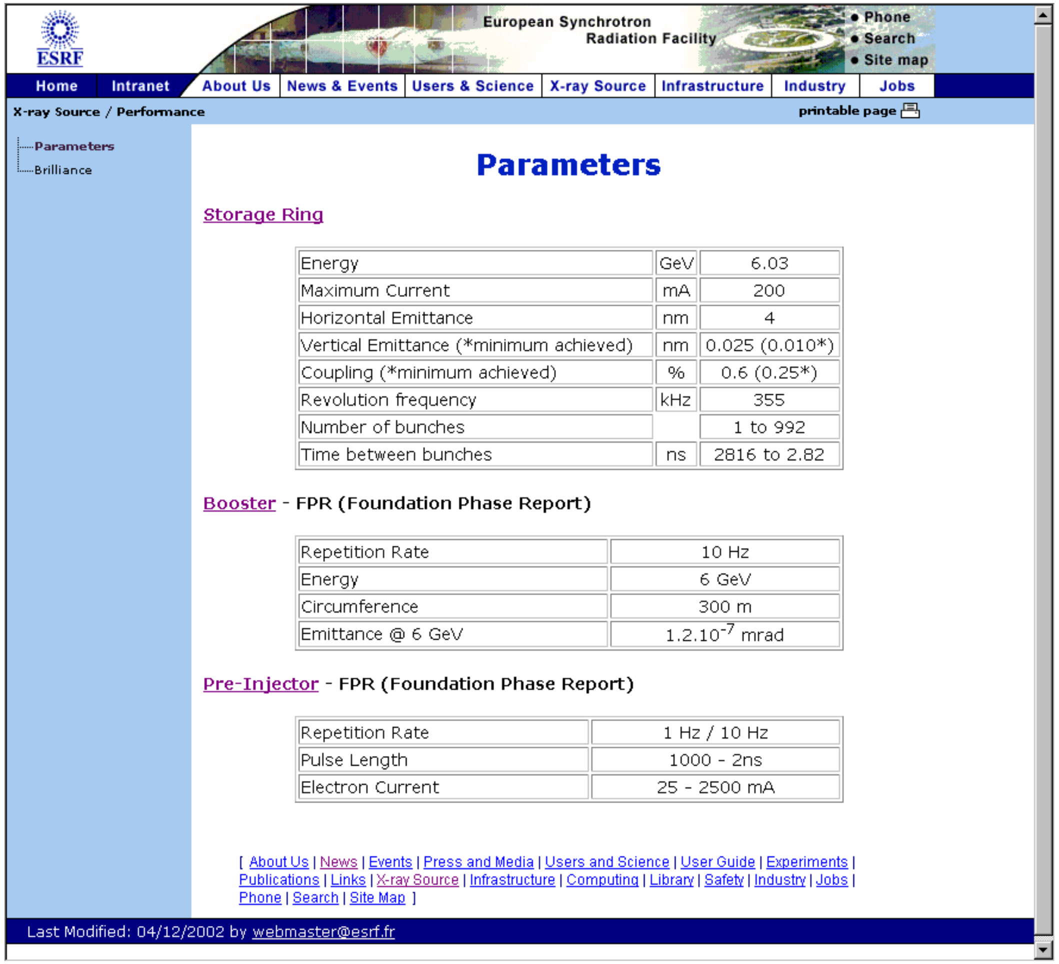
The lifetime, bunch length and energy spread depend on the filling pattern. They are given below for a few representative filling patterns. In both the 16 bunch and the single bunch modes, the energy spread and bunch length decay with the current, the value indicated in the table corresponding to the maximum current. The bunch lengths are given for the usual RF accelerating voltage of 8 MV.

Filling pattern bunch	Uniform	16-bunch	Single
Maximum current (mA)	200	90	20
Lifetime (hours)	75	9	6
Rms energy spread (%)	0.11	0.12	0.22
Rms bunch length (ps)	20	48	73

The main optics functions, electron beam sizes and divergences, at the various points are given below. For insertion device source points, the beta functions, dispersion, sizes and divergences are computed in the middle of the straight section. Two

Performance figures for the ESRF

- *Machine Parameters*



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Parameters
Brilliance

Parameters

Storage Ring

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Booster - FPR (Foundation Phase Report)

Repetition Rate	10 Hz
Energy	6 GeV
Circumference	300 m
Emittance @ 6 GeV	$1.2.10^{-7}$ mrad

Pre-Injector - FPR (Foundation Phase Report)

Repetition Rate	1 Hz / 10 Hz
Pulse Length	1000 - 2ns
Electron Current	25 - 2500 mA

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ESRF Machine parameters

- *Machine Parameters*

- Synchrotron Radiation (SR) from bending magnets has a *continuous spectrum* from infra-red to hard X-rays
- The ESRF bending radius of curvature ρ=23.366 m gives a critical energy ε_{crit}=20.5 KeV
- SR from insertion devices (IDs) gives enhanced photon flux (wigglers) and/or brilliance (undulators)

IMPORTANT FORMULAE:

QUANTITY	*ESRF VALUE (@ 200 mA)*
• Power: $\boldsymbol{P(W) = 88.5 \cdot E^4(GeV) \cdot I(mA) / \rho(m)}$	982 KW (excluding IDs)
• Photon flux: $\boldsymbol{N(ph/s) = 8.08 \cdot 10^{17} \cdot E(GeV) \cdot I(mA)}$	$9.70 \cdot 10^{20}$ (ph/s)
• SR-induced gas load: $\boldsymbol{Q(mbar \cdot l/s) =}$	
$\boldsymbol{= k(\varepsilon > 10\ eV) \cdot N(ph/s) \cdot \eta(mol/ph) \cdot k1(mbar \cdot l/mol)}$	η(mol/ph) · 32.17 (mbar · l/s)
• Desorption yield: $\boldsymbol{\eta(mol/ph)}$	$10^{-1} \div 10^{-6}$ (start-up ÷ well conditioned)

- *Machine Parameters*

BEAM LIFETIME CONSIDERATIONS:

- $1/\tau = 1/\tau_{brems} + 1//\tau_{Touscheck} + 1//\tau_{other}$
- Bremsstrahlung: interaction of the 6 GeV electron beam with the residual gas:
  strongly dependent upon atomic number of residual gas molecules

$$d\sigma/du \sim 4\cdot\alpha\cdot r_e^2\cdot Z\cdot (Z+1)\cdot 4/3/u\cdot (1-u+0.75u^2)\cdot \ln(184.15/Z^{1/3})$$

- Touscheck effect: intra-beam scattering (important at high bunch currents)
- horizontal and/or vertical aperture of vacuum chambers *are* important

- *Conductances*

In a tubulated vacuum system, like that of an accelerator, the following equations hold:

$$Q(x) = - w \cdot dP/dt$$

$$dQ/dx = A \cdot q$$

where:

Q = gas flow (mbar · *l*/s); **A** = specific surface area (cm^2/m); **q** = outgassing yield (mbar · *l*/s/cm^2); **w** = specific conductance (*l* · m/s)

If L(m) is the distance between pumps of equal pumping speed S (l/s), and q and A are constant, the following equation for the pressure profile is obtained

$$w \cdot d^2P/dx^2 = - A \cdot q$$

which is readily integrated to obtain a useful analytic expression for the pressure profile

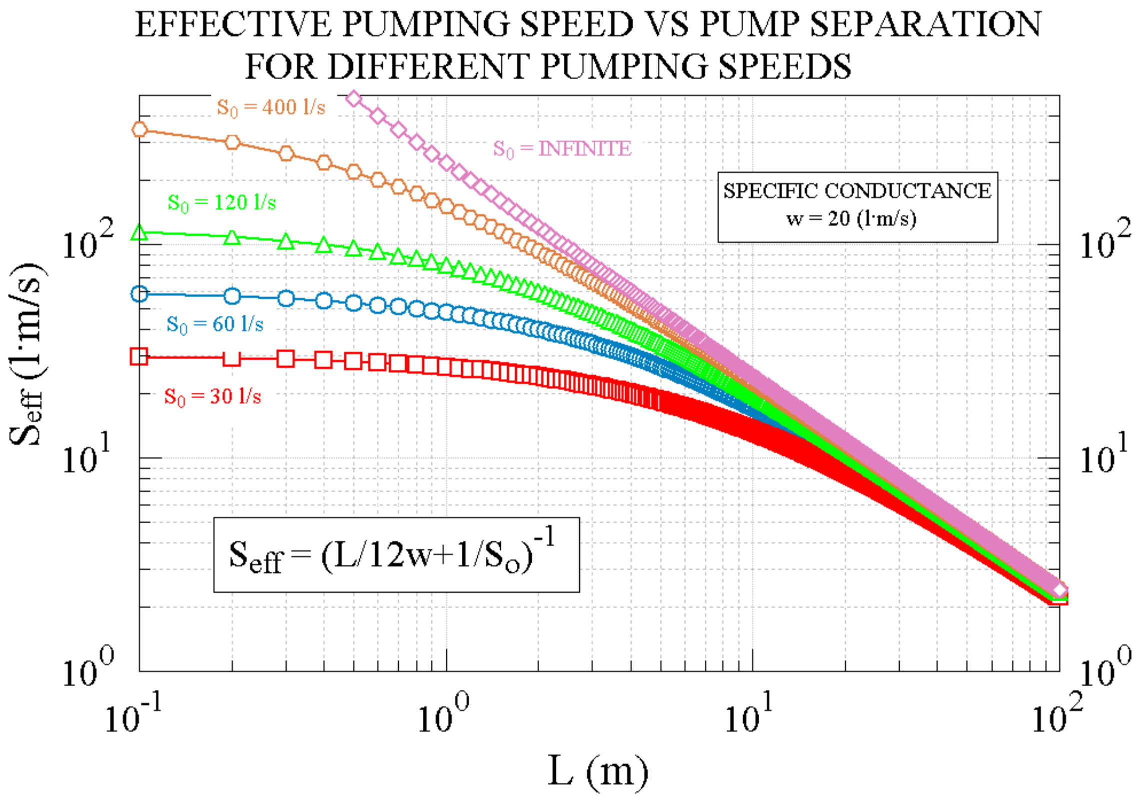
$$P(x) = ½ \cdot A\, q / w \cdot (2\, L\, x - x^2) + A\, q\, L/S$$

The average pressure is

$$<P> = A\, q\, L / S_{eff}, \text{ where } S_{eff} = (1/12 \cdot L / w + 1/S)$$

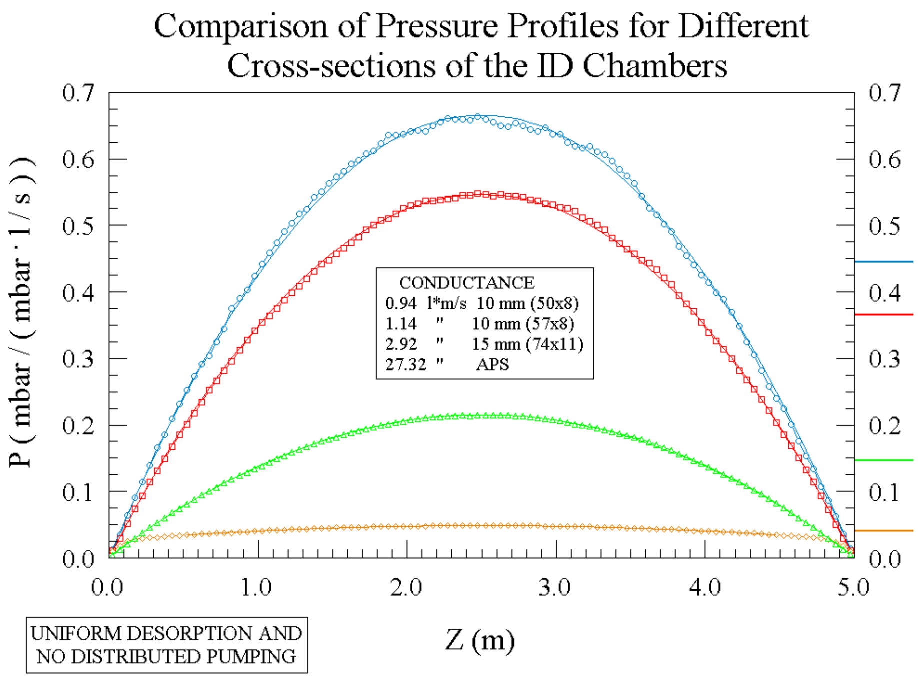
Therefore, even for S→∞ $<P>$ is limited by w!

- *Conductances*



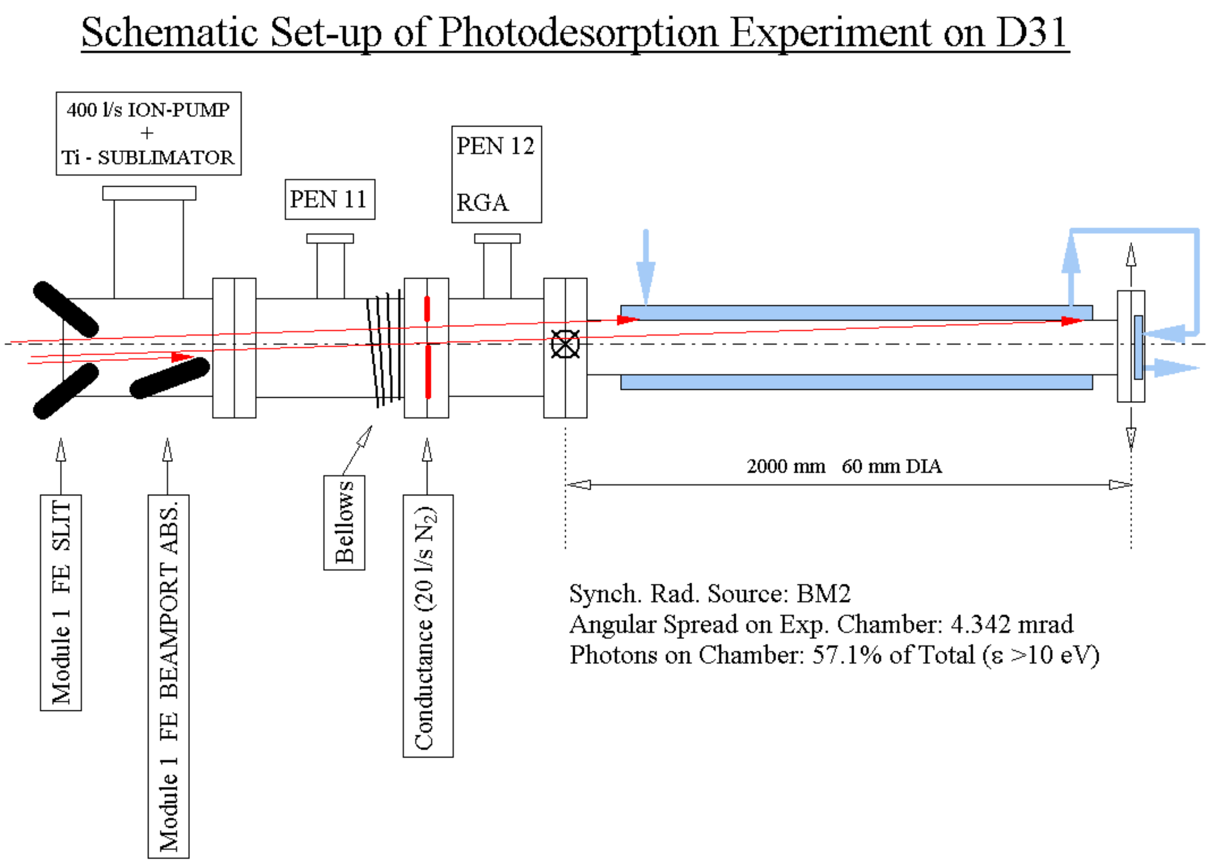
Effective pumping speed as a function of installed speed and distance between pumps

- *Conductances*



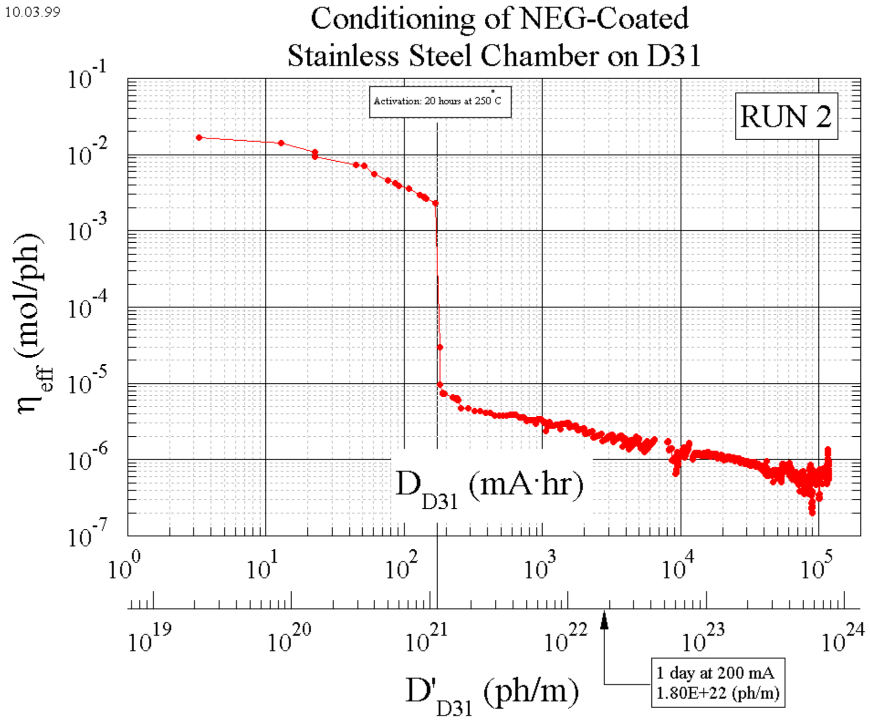
Effect of different specific conductances w (*l* · m/s) for the same thermal desorption coefficient q (mbar · *l*/s/cm^2). The average pressure <P> is inversely proportional to w.

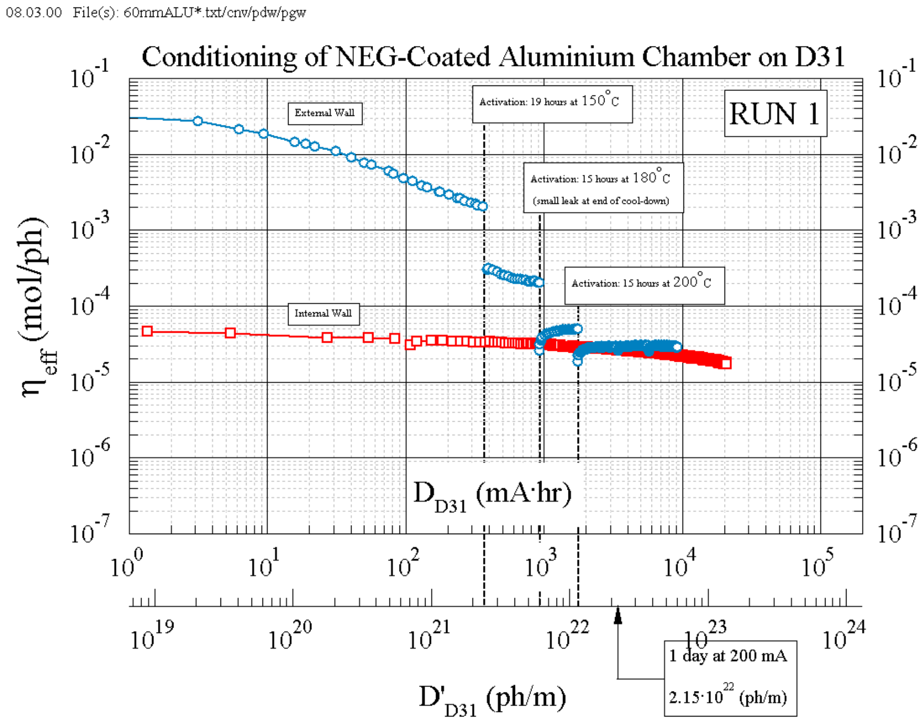
- *NEG-Coated Chambers* RADIATION SAFETY REQUIREMENT! *(European Directive, 2000)*



- *NEG-Coated Chambers*

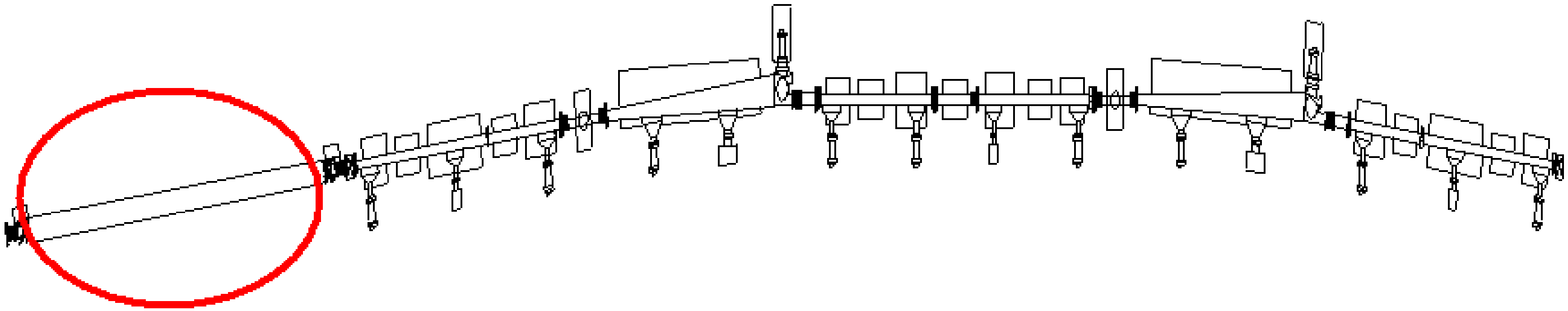
Photodesorption measurements on D31





- *ERFR lattice and vacuum system*

The 844 m ring is divided into 32 cells. Each cell has a ~ 6m-long straight section and a ~ 20m-long common part which hosts the dipole and achromat chambers

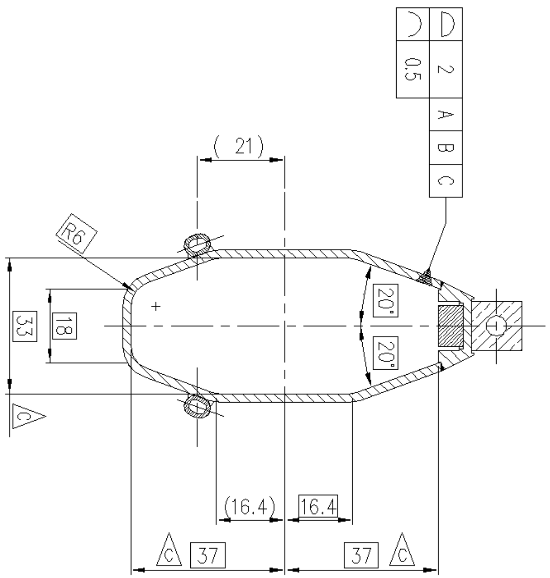


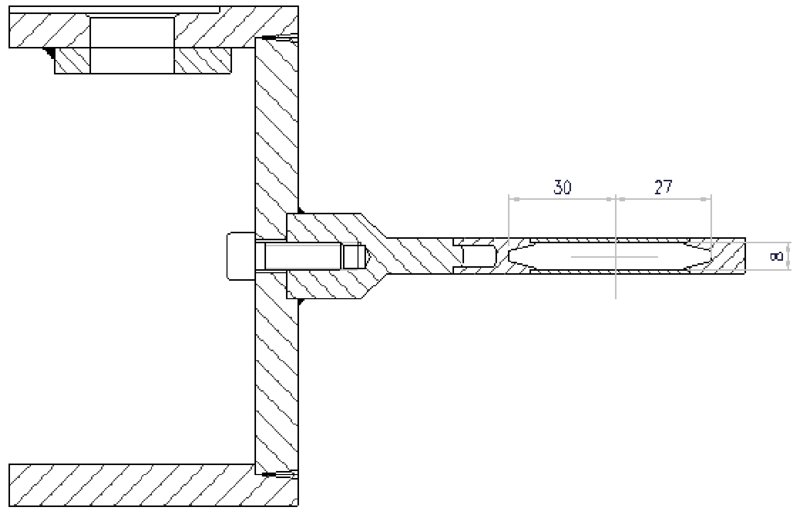
CELL: 1/32nd of the ESRF storage ring.
The straight section is highlighted

The “achromat” cross-section a) is the more common around the ring (~ 50% of it)

- *ERFR lattice and vacuum system*

Vacuum chambers





a) “achromat” chamber:

316LN+OFHC absorber (brazed)

C = 15.4 *l*·m/s

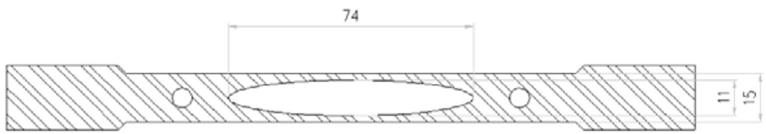
b) “10mm” SS chamber

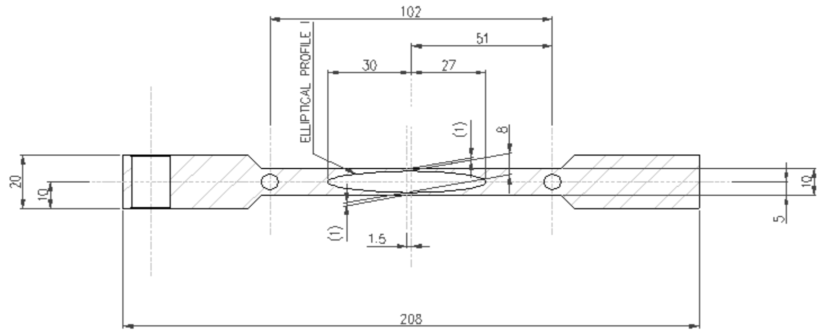
316LN sheet with 50µm Cu

C = 1.14 *l*·m/s

- *ERFR lattice and vacuum system*

Vacuum chambers





c) “15mm” extruded-Al (+NEG)

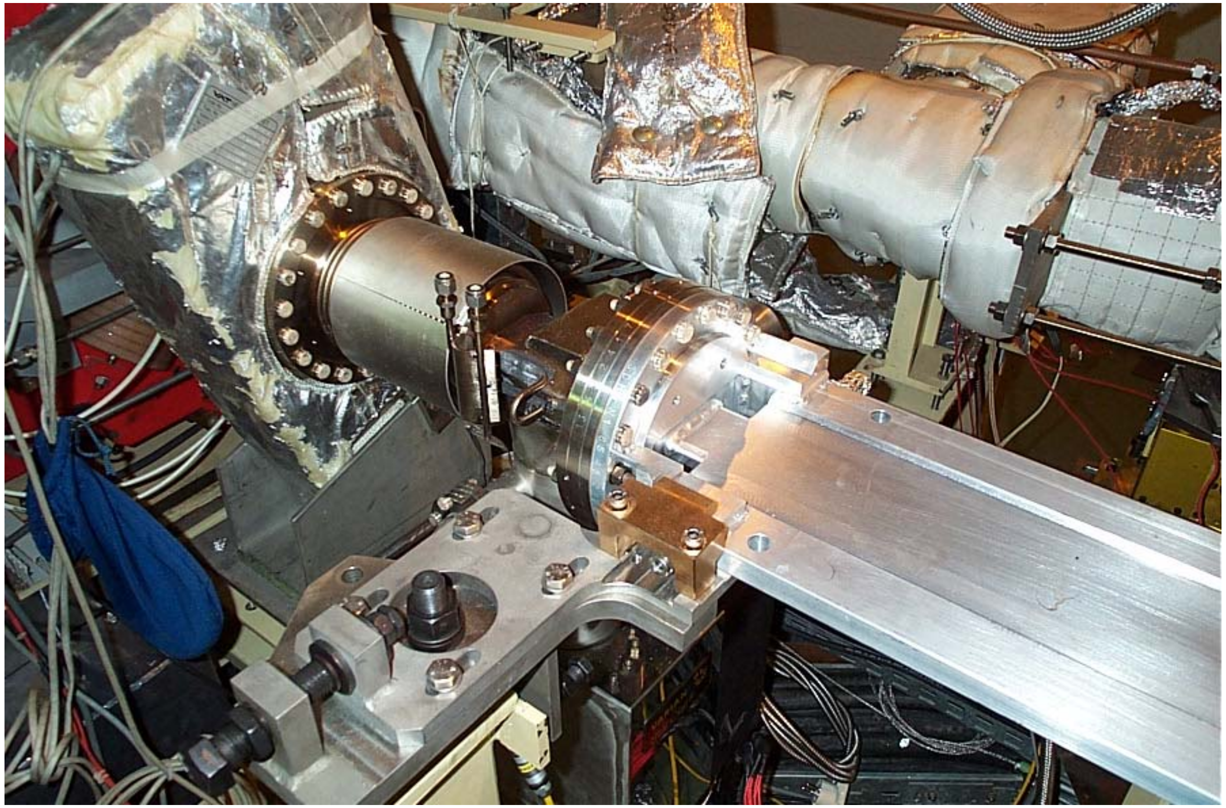
C = 2.92 l·m/s

d) “10mm” extruded-Al (+NEG)

C = 0.94 l·m/s

- *ERFR lattice and vacuum system*

Vacuum chambers

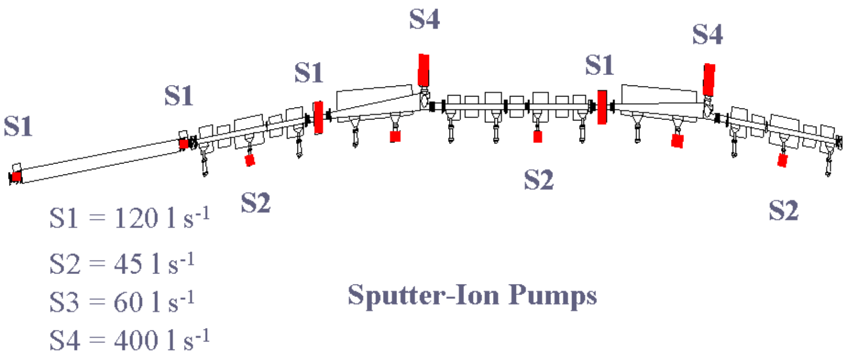


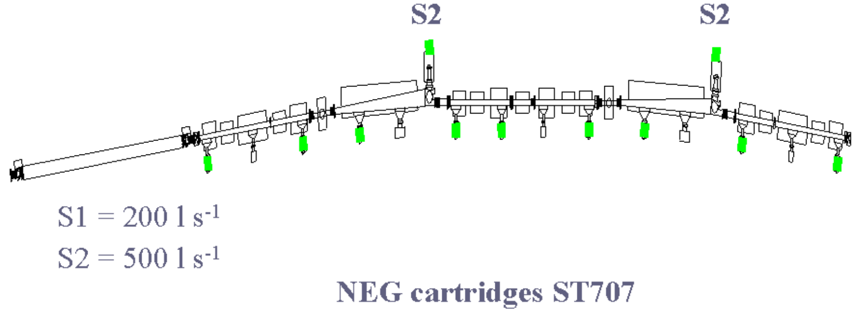
"10mm" extruded-aluminum CV5073 on ID6. Also visible are the gate valve and the sliding joint/bellows/BPM/absorber chamber (with ion-pump and Penning gauge).

- *ERFR lattice and vacuum system*

Pumping

Pumping in the ESRF storage ring is given by ion-pumps (Varian StarCell), NEG-pumps (SAES Getters GPx00), Ti-sublimation pumps (Balzers, Varian), and NEG-coatings (CERN, ESRF)

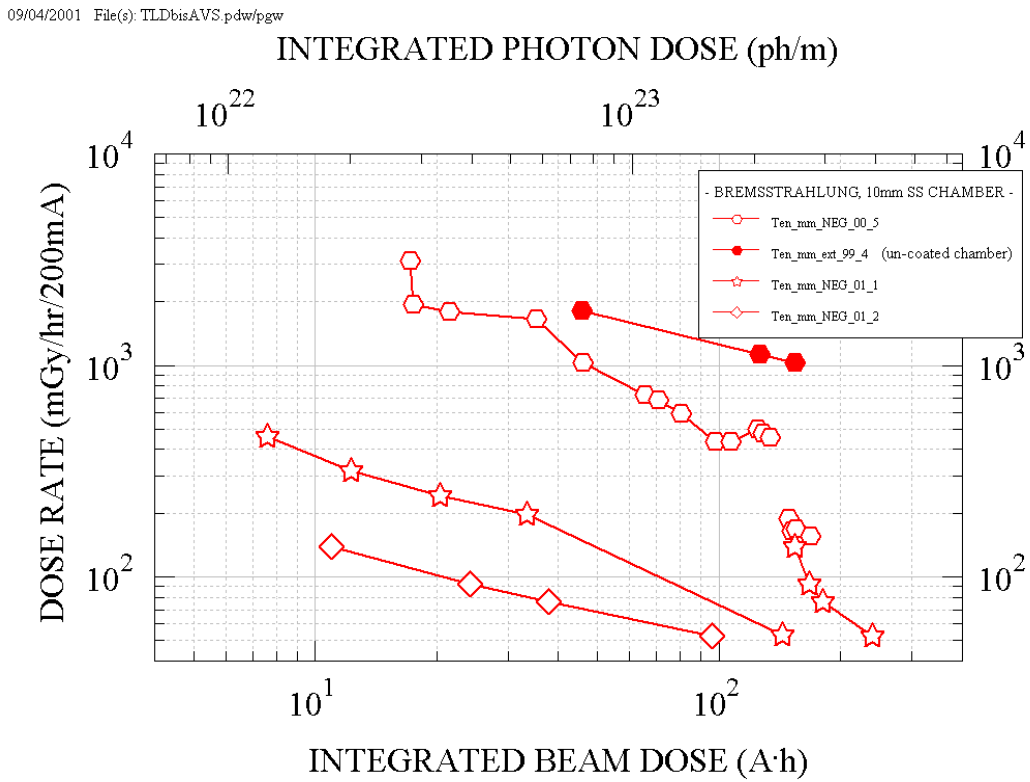




Pump location and size along a standard cell
Crotch absorbers are pumped by one-400 l/s IP and one-GP500 NEG pump

- *Machine physics issues and vacuum performance*

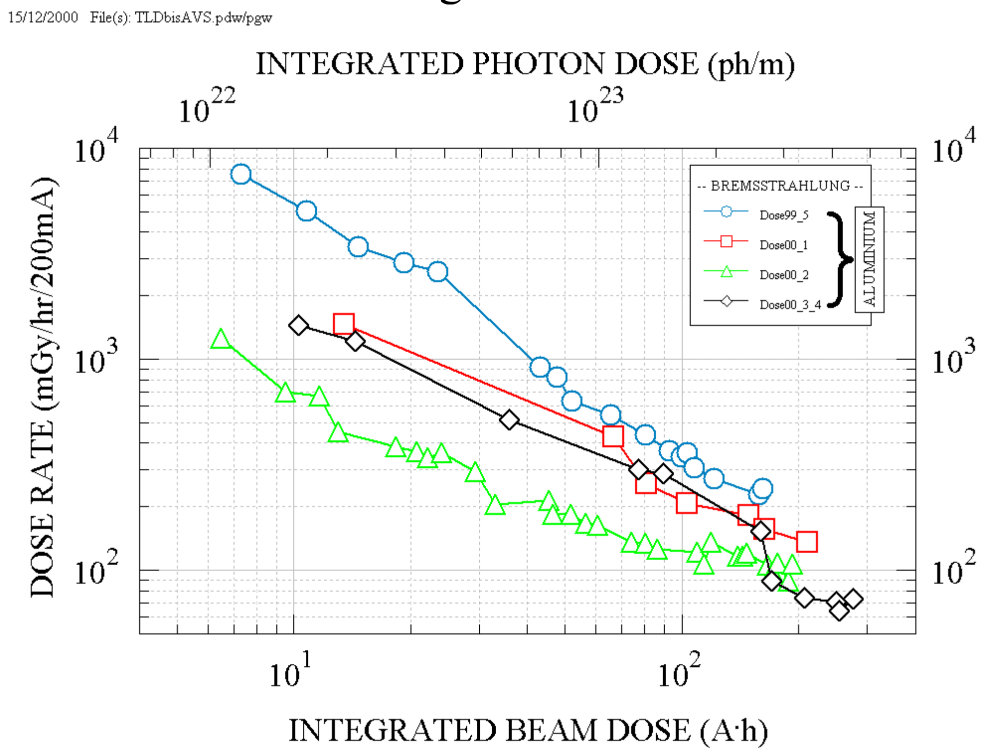
Bremsstrahlung measurements – ID31



BS measurements on ID31: stainless steel, “10mm” chambers

- *Machine physics issues and vacuum performance*

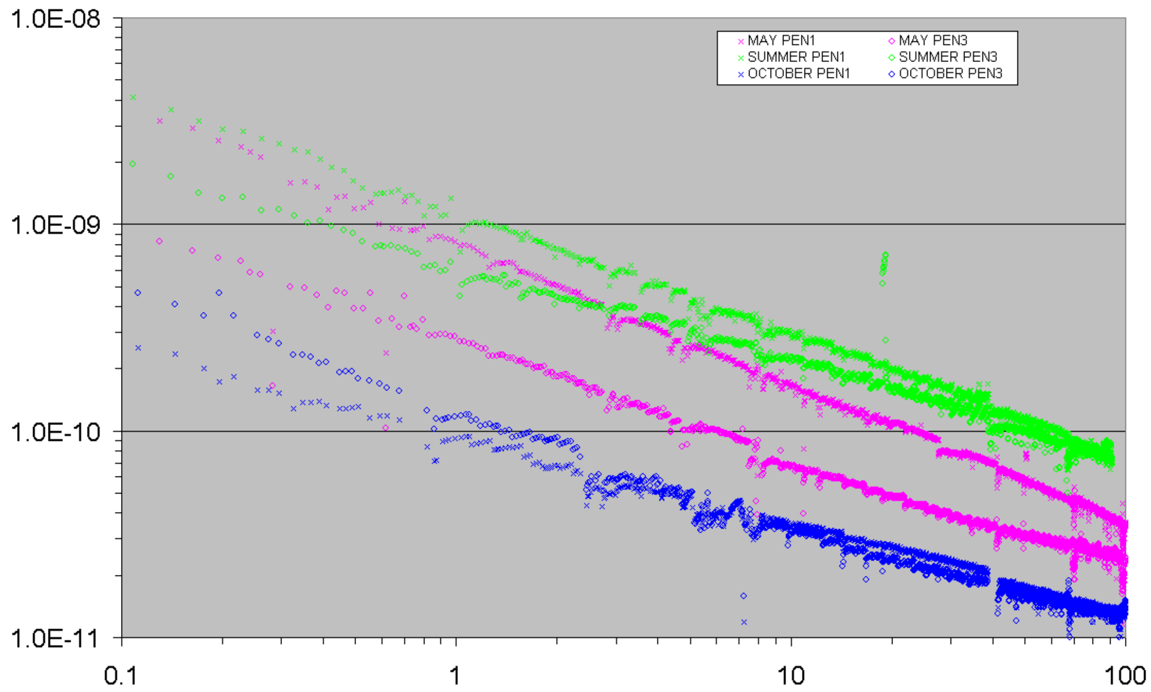
Bremsstrahlung measurements – ID31



BS measurements on ID31: extruded aluminum, "15mm" chambers

- *Machine physics issues and vacuum performance*

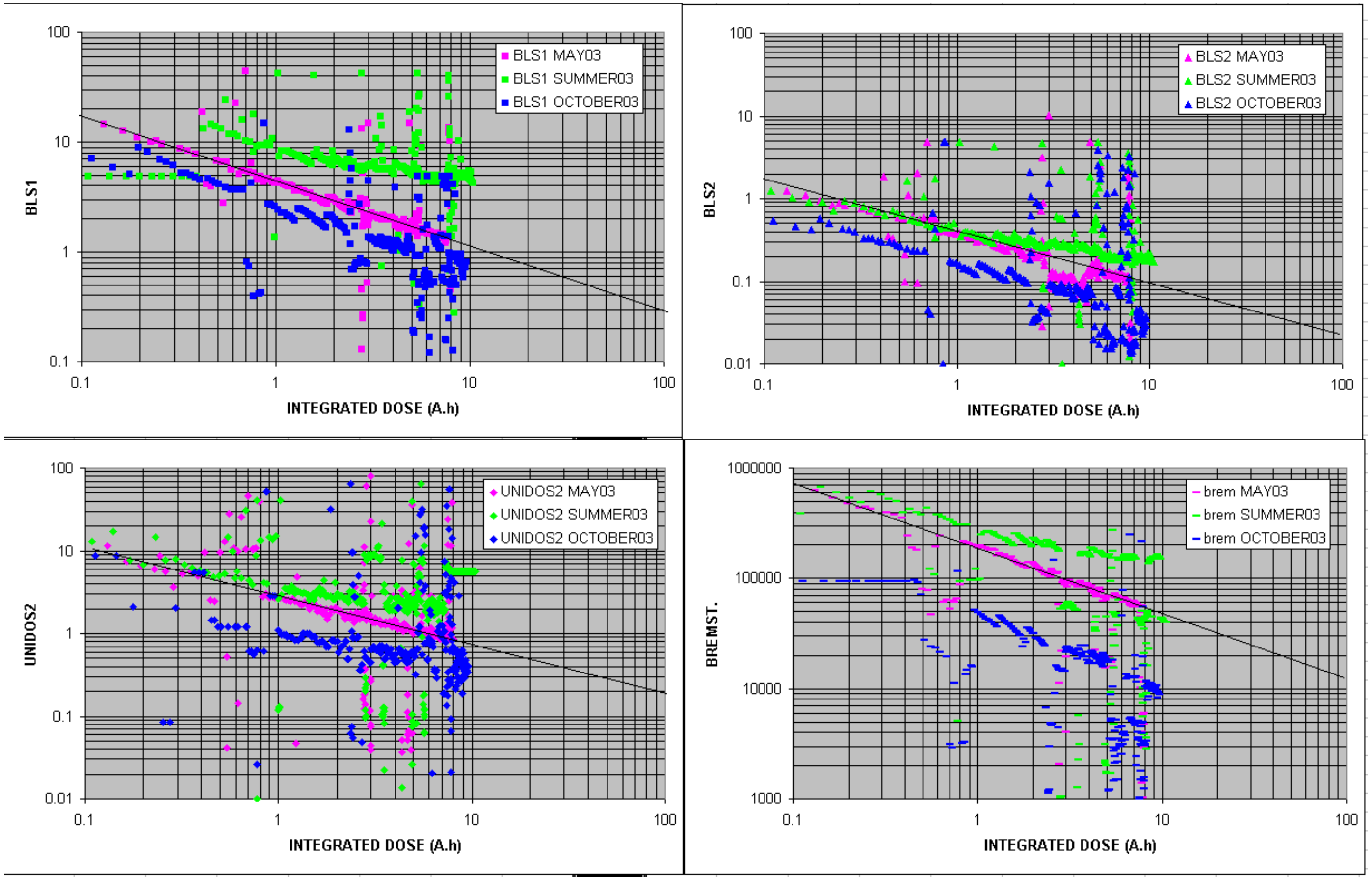
Vacuum conditioning – ID6



Dynamic pressure (mbar/mA) vs accumulated beam dose (A·h) for three different extruded aluminum, "10mm" chambers.

- *Machine physics issues and vacuum performance*

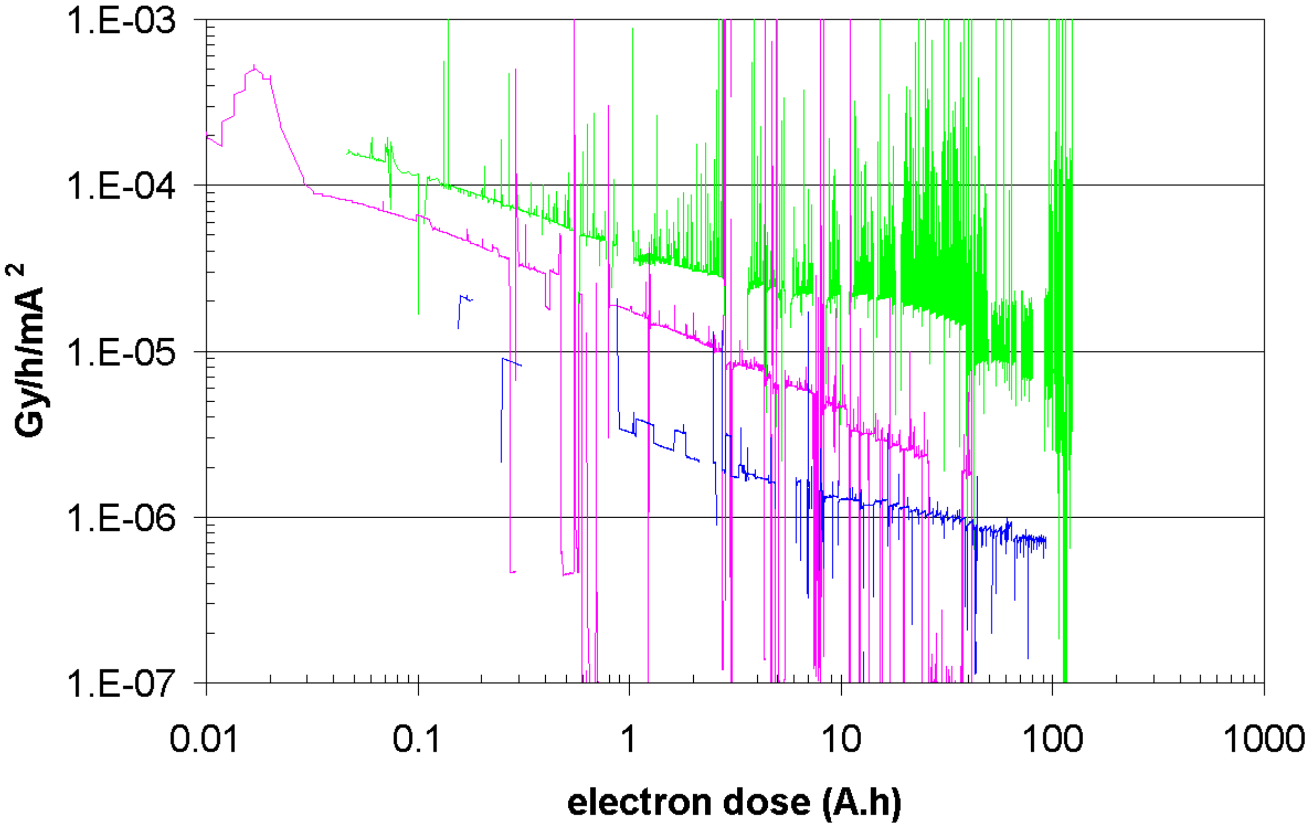
Machine beamloss detector measurements – ID6



BLS#: beam loss detector on dipole #; UNIDOS/BREMS detectors

- *Machine physics issues and vacuum performance*

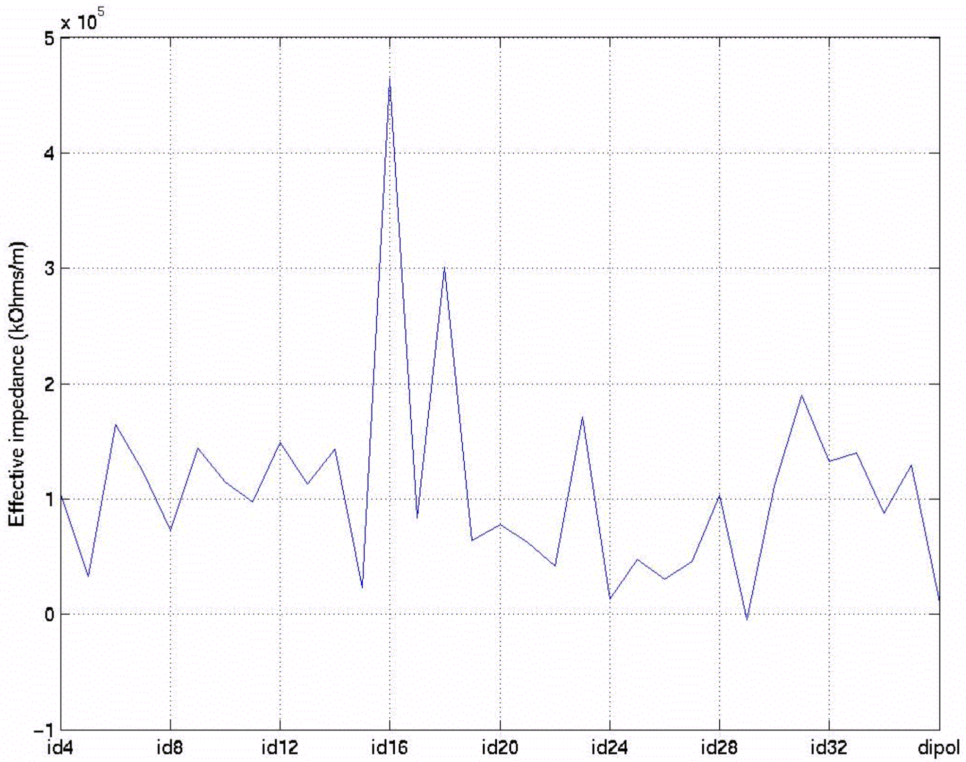
Bremsstrahlung measurements – ID6



Bremsstrahlung measurements on ID6, same chambers as before (courtesy of P. Berkvens, ESRF)

- *Machine physics issues and vacuum performance*

Machine impedance measurements



(courtesy of T. Perron, ESRF)

- *Machine physics issues and vacuum performance*

Machine impedance measurements (and calculations)

SOLEIL SYNCHROTRON

Impact of NEG Coating on the Impedance

11th ESLS Workshop, 17 ~ 18 November 2003,
ESRF, Grenoble, France

Ryutaro Nagaoka
Synchrotron SOLEIL

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4. **Effective resistivity of NEG**
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6. **Impact on SOLEIL**
7. **Conclusion**

Impact of NEG Coating on the Impedance
11th ESLS Workshop, 17~18 November 2003 11/11

__7 Conclusion__

◊ The NEG coated chamber impedance was estimated with formulae that take into account a metallic layer on the chamber surface.

◊ Found that $\mathrm{Im}(\mathbf{Z})_{eff}$ increases by ~50% with 1 μm coating, while $\mathrm{Re}(\mathbf{Z})_{eff}$ remains roughly unchanged.

◊ Fortunately, $\mathrm{Im}(\mathbf{Z})_{eff}$ saturates rather fast in both $\boldsymbol{\rho}$ and $\boldsymbol{d}$.

◊ The increase of $\mathrm{Im}(\mathbf{Z})_{eff}$ would have a non-negligible impact of reducing $(I_{th})_{TMCI}$ on SOLEIL ring.

◊ To explain the anomalous observation in ELETTRA, one has to assume $\boldsymbol{\rho} >> \boldsymbol{\rho}_{<elements>}$ and $\boldsymbol{d} >> 1$ μm.

Acknowledgement

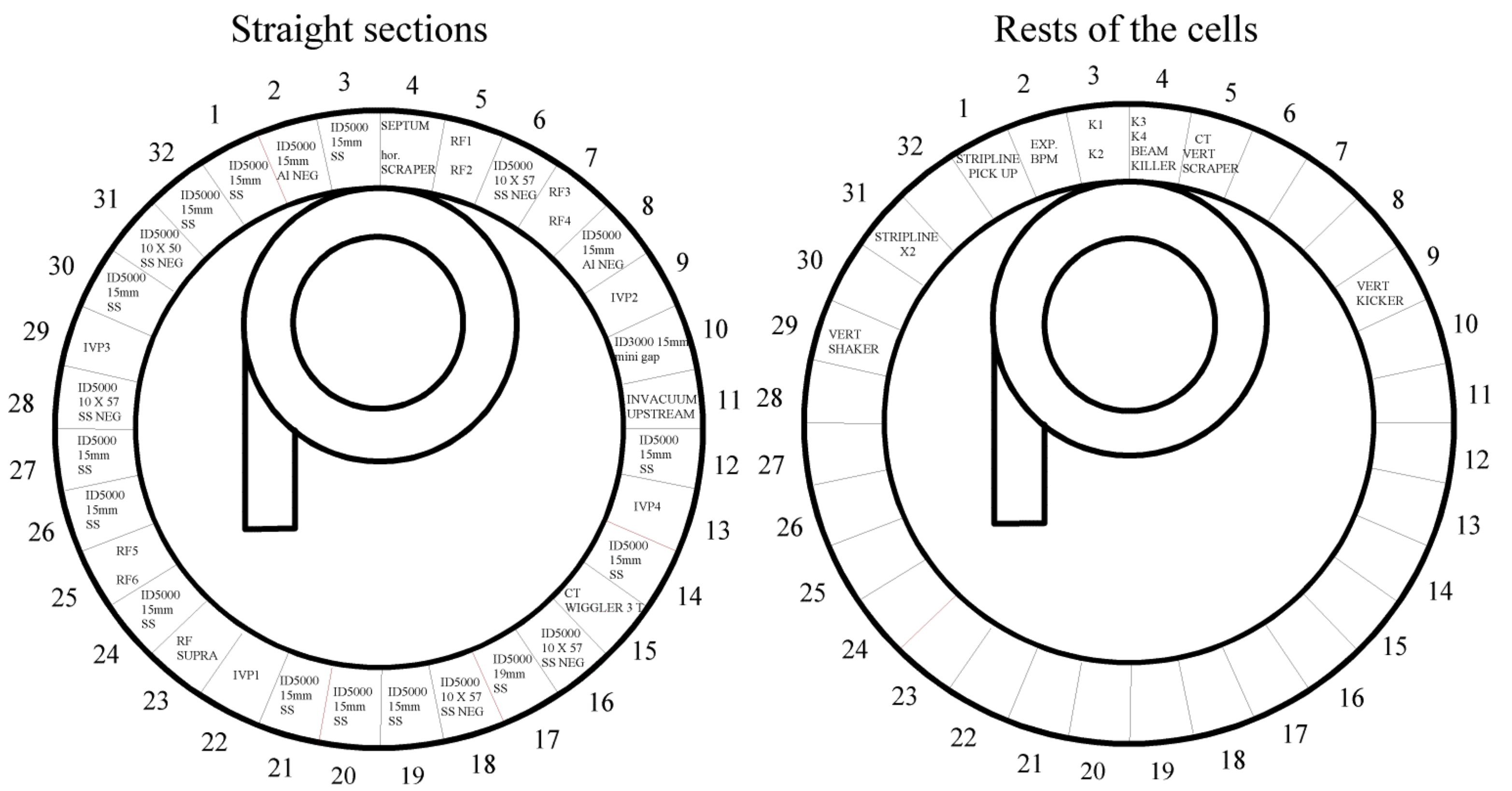
The author is grateful to Emanuel Karantzoulis (ELETTRA) for having provided him with experimental data as well as discussions on the analysis. Thanks are also to C. Herbeaux, J.M. Filhol, R. Kersevan (ESRF), P. Marchand, M.P. Level, E. Plouviez (ESRF) for useful discussions.

(courtesy of R. Nagaoka, SOLEIL)

- *Machine physics issues and vacuum performance*

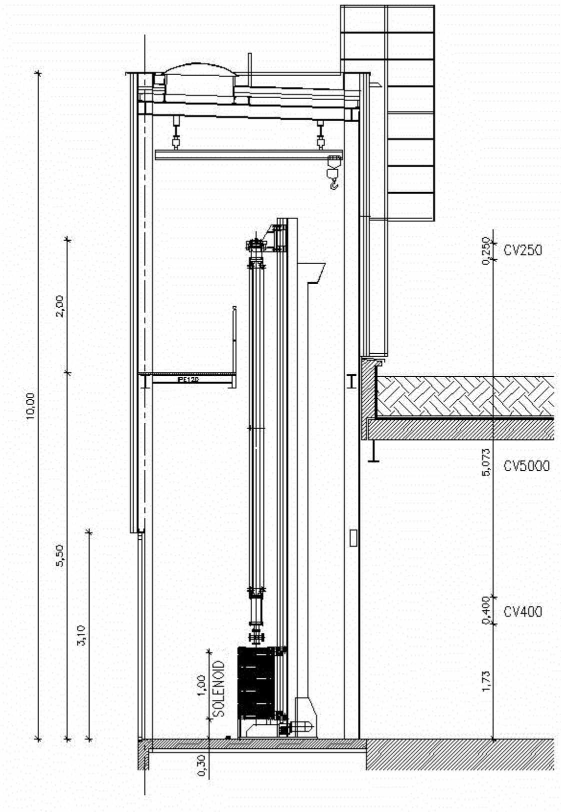
NEG-coated ID chambers: storage ring status (IVP#=in-vacuum undulators+2m long Al/NEG Chambers)

WHAT is WHERE ?



- *R&D*

NEG-coating: Main R&D issue at the ESRF is the NEG-coating of long, narrow ID vessels



Schematics and view of NEG-coating facility at ESRF, operational since November ‘02

- *R&D*

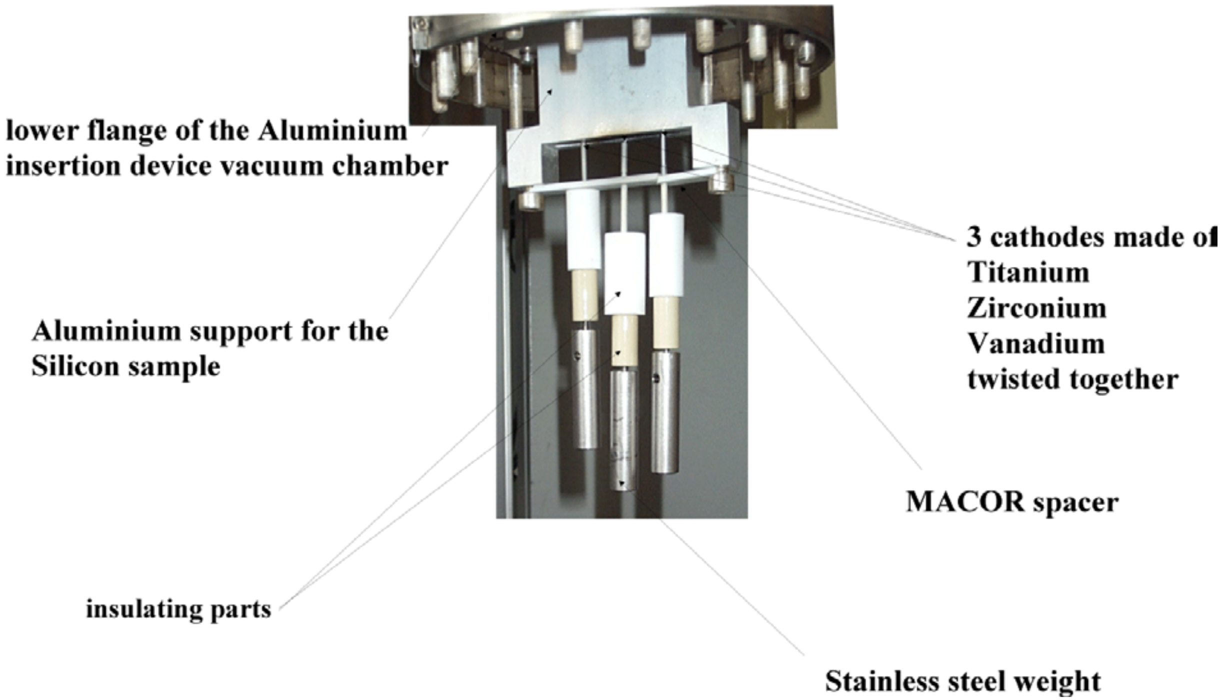
NEG-coating

One extruded aluminum, "10mm" CV5073 being coated at the ESRF

- *R&D*

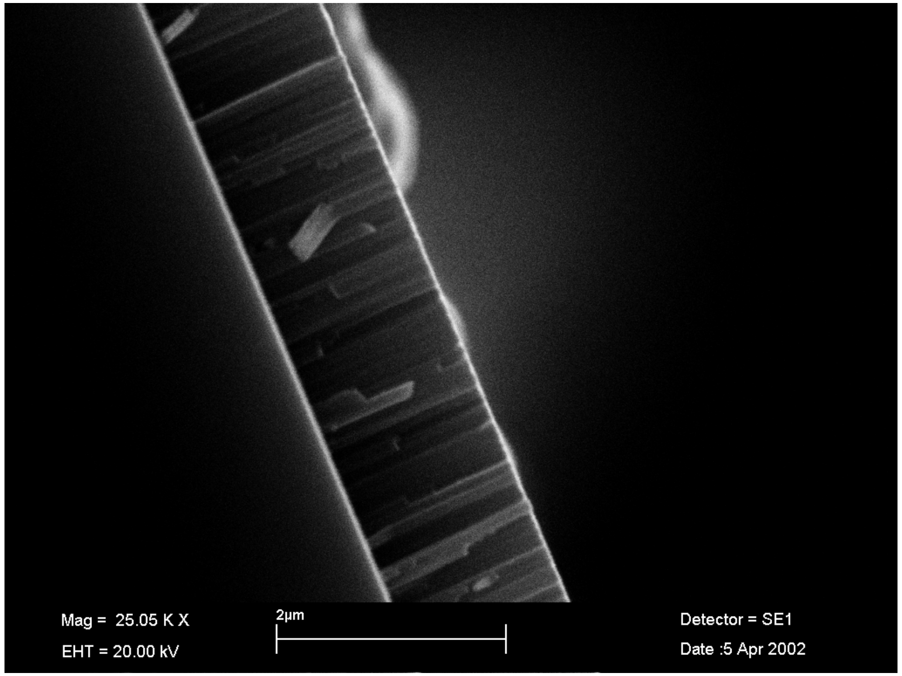
NEG-coating

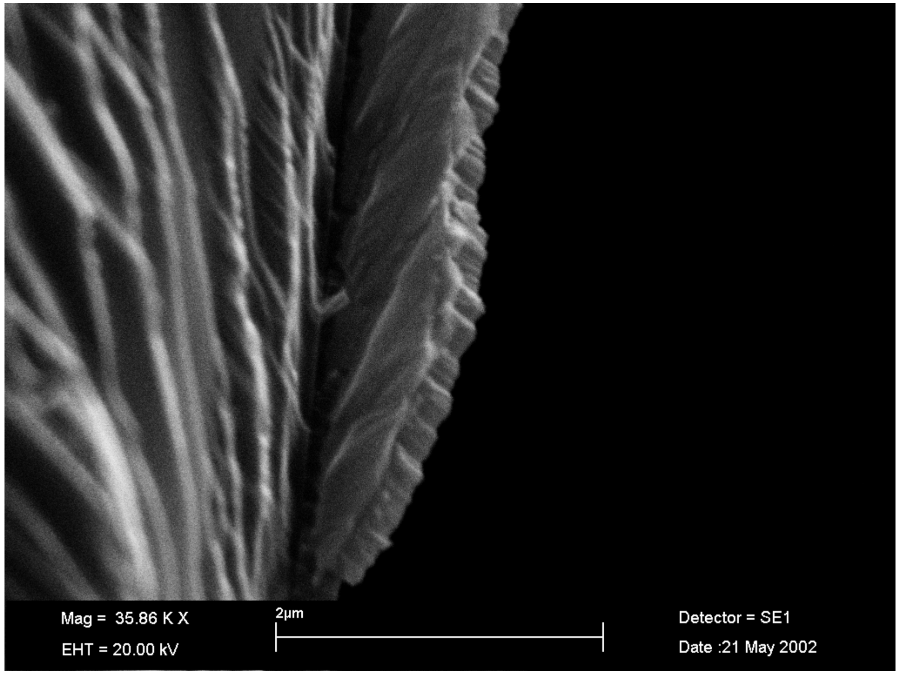
BOTTOM ASSEMBLY OF THE 3 CATHODES



Coupon holder and insulating ceramic spacers on the bottom of the chamber under coating

- *R&D*





Views of Ti-Zr-V NEG coatings on silicon coupon (courtesy of I. Snigireva, ESRF)

- *Acknowledgements*

Many thanks to the ESRF Vacuum, Machine, Mechanical Engineering, Safety, and Operation groups. I am indebted with P. Berkvens, T. Perron, and R. Nagaoka (SOLEIL) for providing some slides.

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